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PLEXIGLAS

DESIGN MANUAL



ROHM & HAAS COMPANY

WASHINGTON SQUARE, PHILADELPHIA 5, PENNA.



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PLEXIGLAS* is an acrylic plastic manufactured by the Rohm & Haas Company. It is produced in sheets of various sizes, in flat or corrugated form with smooth or patterned surfaces, and as rods and molding powders. Colorless in its natural state and as clear as the finest optical glass, the material is also manufactured in a full range of transparent, translucent and opaque colors.

PLEXIGLAS* is noted for its sparkling beauty, light weight, strength, resistance to breakage, chemicals and weather, and the ease with which it may be formed and machined.

** PLEXIGLAS is a trade mark, Reg. U. S. Pat. Off.*

STUTTEN: BLBAAT
AIR BOA JH²

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This is one of a series of technical booklets covering optical properties, mechanical properties, fabrication and installation of Plexiglas.

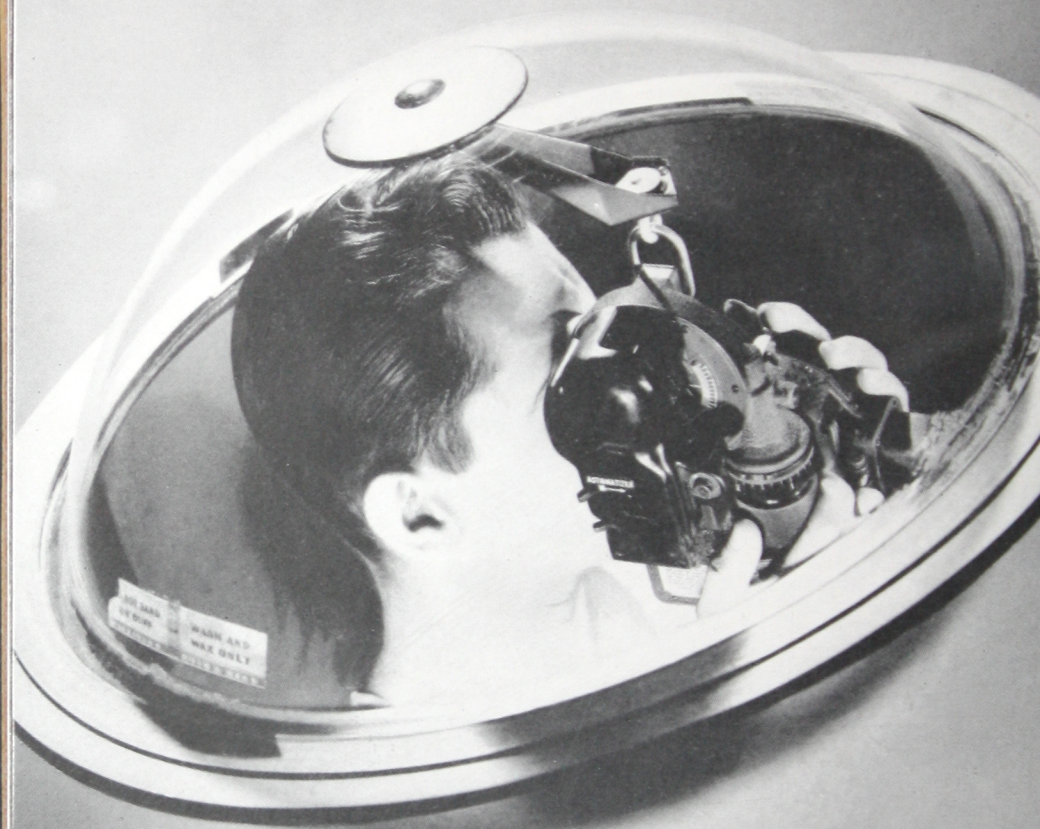


PLEXIGLAS

has found wide application in many fields. In some cases it is used because of its excellent optical qualities—its perfect transparency, efficient reflection and ability to “pipe” light. In others it is used because of its dimensional stability and resistance to weathering. Other applications take advantage of the permanence of its electrical insulating qualities which are practically unaffected by weathering or water immersion. Still others require its high impact strength and other mechanical characteristics. Most applications make use of its superior fabricating or molding properties.

To assist designers in taking full advantage of all of these properties, we have prepared this manual. It does not attempt to cover such design fundamentals as proportion, line, shape or color. It does point out possibilities and outline limitations of design in transparent plastics.

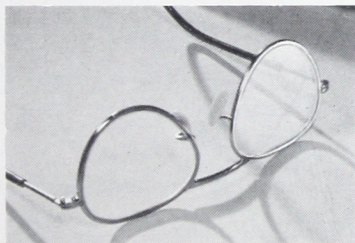
SECTION 1 OPTICAL



CONSIDERATIONS

Because Plexiglas has such excellent physical properties, there is a tendency for an engineer to think of it first from a mechanical aspect. In most cases, however, this transparent plastic is used primarily for “see-through” rather than structural parts. In the proper design of these parts, attention must be given to the laws of optics.

The considerations raised in the following pages apply not only to the design of Plexiglas parts for aircraft, but also to the design of Plexiglas goggle lenses, safety shields, dial covers, inspection windows, or, in fact, to any other “see-through” parts—where an observer must look through Plexiglas or any other transparent material.



*PLEXIGLAS safety goggles
(Willson Products, Reading, Pa.)*

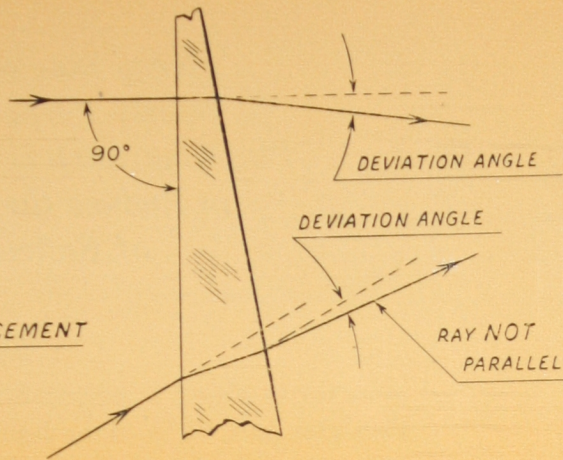
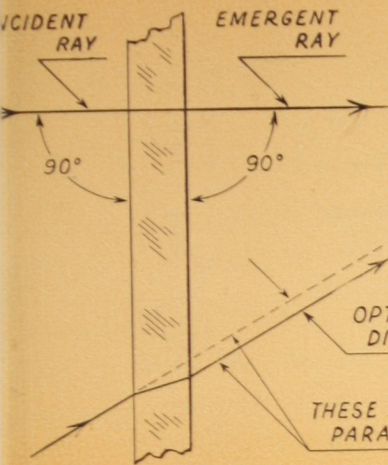
***Keep Line of Sight
as Nearly Perpendicular to
Plexiglas Surface as Possible
to Reduce Optical Deviations to
a Minimum***

Even with the most advanced manufacturing methods, it is impossible to cast a transparent plastic sheet with two *perfectly* plane and parallel surfaces. In this respect, Plexiglas sheets come close to perfection and are superior to most glass, with the possible exception of polished plate glass.

Variations from the parallel show up in the form of localized, slightly wedge-shaped cross-sections. When a line of sight is perpendicular to the surface, the deviations caused by such variations are kept as low as five or six minutes of arc for regular Plexiglas sheet production and are negligible for most applications.* However, viewing through the panel at an angle exaggerates this deviation, as shown in Figure B, so that it may be objectionable in critical cases.

Plexiglas can be compression or injection molded with very small deviations of line of sight provided that molds are constructed with this requirement in mind.

* Cast sheets with lower deviations, at least over a limited area, can be selected to specification. This is known as "Optical Grade" Plexiglas.

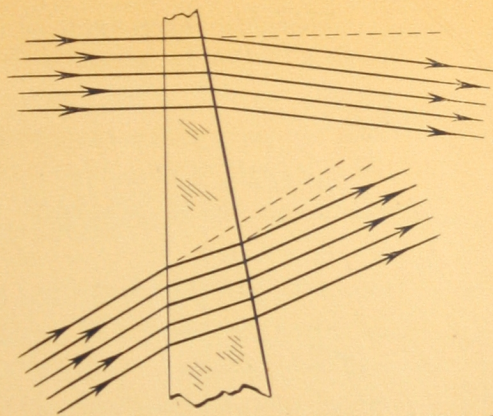
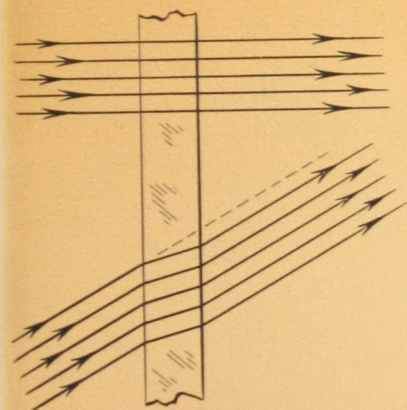


LIGHT TRAVELS IN STRAIGHT LINES

WHEN SURFACES ARE $\parallel$ THE EMERGENT BEAM IS ALWAYS $\parallel$ TO THE INCIDENT RAY — THE PARALLEL OFFSET WHICH OCCURS WHEN INCIDENT RAY IS AT ANGLE TO SURFACES IS KNOWN AS OPTICAL DISPLACEMENT

LIGHT TRAVELS IN STRAIGHT LINES

IN ADDITION TO OFFSET WEDGED SURFACES PRODUCE OPTICAL DEVIATION



OPTICAL DISPLACEMENT

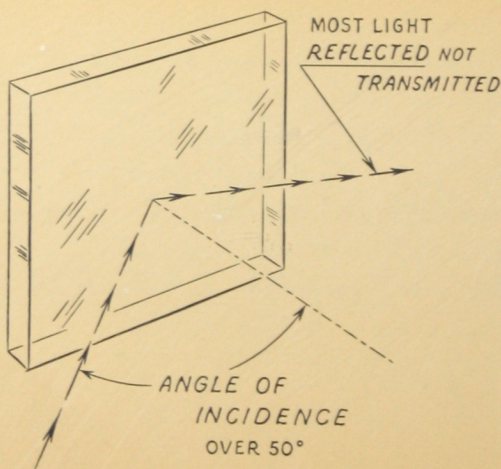
OPTICAL DEVIATION

***Keep Line of Sight
as Nearly Perpendicular to
Plexiglas Surface as Possible
to Reduce the Amount
of Reflection***

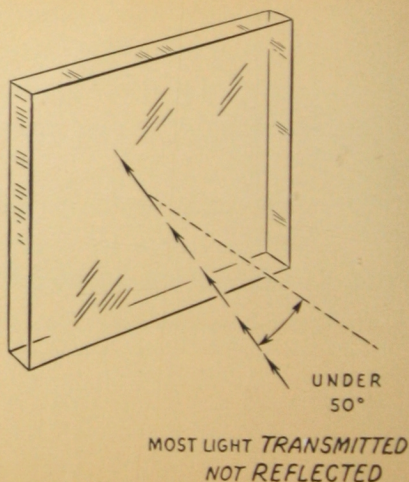
When the line of sight from observer to object is perpendicular to the surface of a Plexiglas part, 92% of the light is transmitted and only 8% reflected. However, as this line moves away from the perpendicular, a greater percentage of light is reflected. If the angle of incidence reaches 85%, light transmission of Plexiglas—or other transparent material—drops to practically zero, and the observer will see almost nothing but reflections.

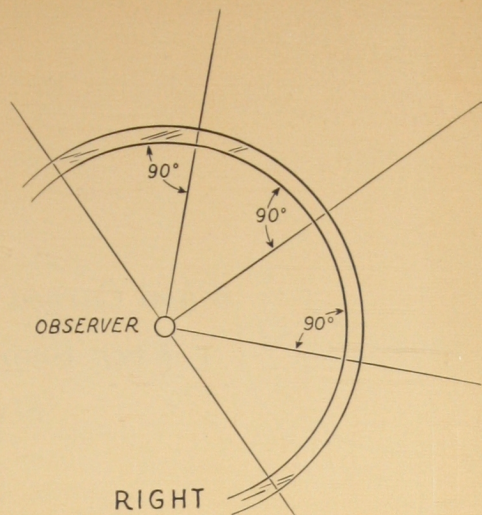
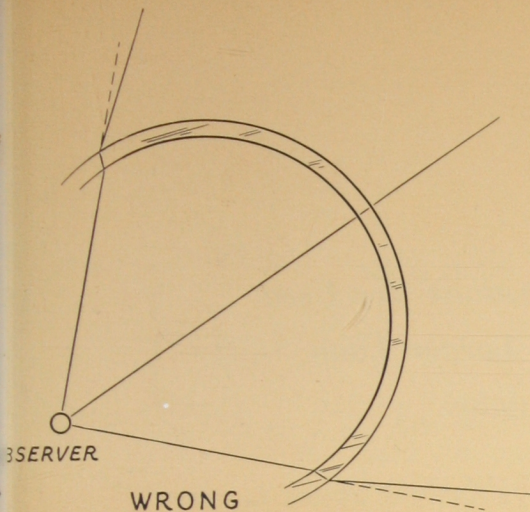
Therefore, keep angle of incidence below 50°.

WRONG



RIGHT





***When Curved Panels
Are Necessary, Use Simple
Cylindrical or Spherical Shapes,
Preferably with Observer at
Center of Curvature***

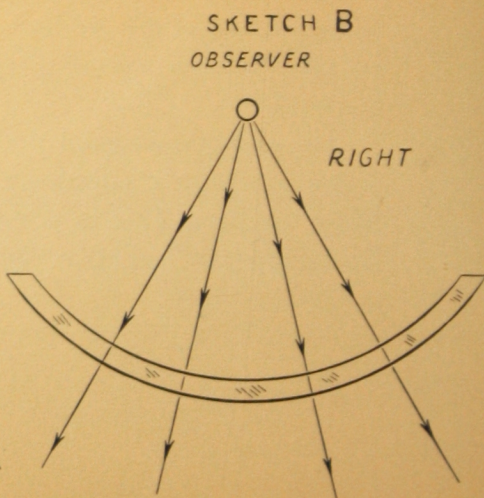
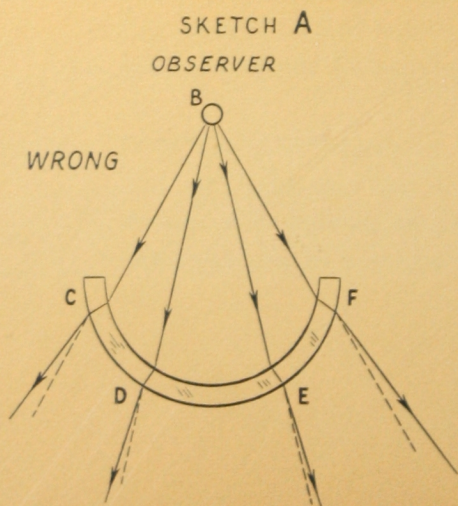
When the observer is at the center of curvature of a cylindrical or spherical shape, it is obvious that all lines of sight will be perpendicular to the surface of the plastic—so that full advantage will be taken of the optical properties of the transparent material.

An example of good optical design in this respect is the navigator's astrodome found aboard Army and Navy bombers. This is a shallow section of a sphere. Deviations are less than two minutes of arc from the mean.

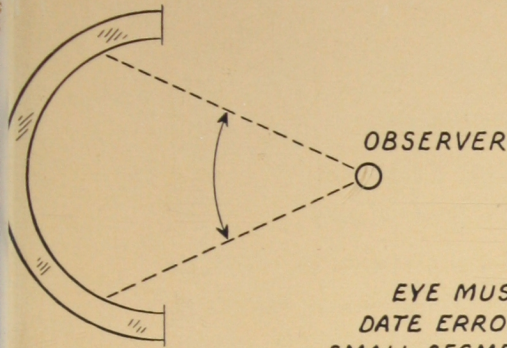
***When Curved Sections Are Used,
Keep Radius Larger Than
Six Inches***

As shown in Sketch A, a line of sight originating with an observer at "B," would be transmitted with minimum deviation only in a relatively small section of the total area. In areas "C-D" and "E-F," of Sketch A, where the angle of incidence is high, the reflection losses would be great and astigmatic and wedge-effects exaggerated.

Also, as a practical fabricating or molding consideration, the flow of material is difficult to control when the panel has a small radius of curvature. Plexiglas parts with radii over six inches are easier to form and are superior optically.

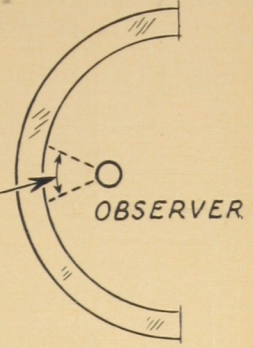


RIGHT



WRONG

Eye must accommodate errors of only small segment of panel



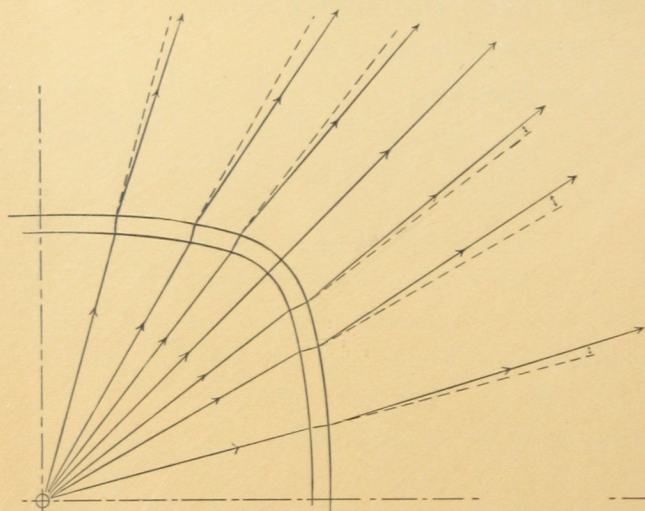
*When a Sharp Radius of Curvature
Is Necessary, Keep the Panel
as Close to the Observer's
Eye as Possible*

Since the eye can encompass only a limited arc, keep the panel close to the observer's eye so that it will have to accommodate only the comparatively small range of errors which would be found in a small section of the panel rather than try to compensate for the total errors of the whole panel.

Avoid Changes of Radii of Curvature, Especially Quick Changes

When the radius of curvature changes rapidly, a single observer obviously cannot always be at the center of the curvature. In other words, the angle of incidence of the line of sight may vary from perpendicular to a wide angle, introducing—to a varying degree—the wedge-effect mentioned on page 8 and the reflection losses mentioned on page 10.

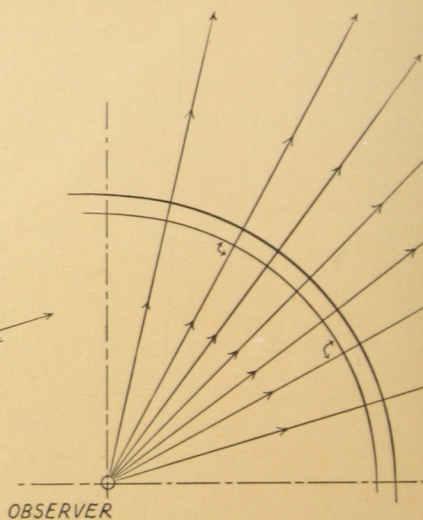
Curves should be blended into each other as gradually as possible. A splined curve is better than tangent circles, since an abrupt change in radius of curvature introduces an abrupt change in deviation at the point of mutual tangency.



OBSERVER

VARYING ANGLES OF INCIDENCE
CAUSE HIGH AND VARYING DEVIATIONS

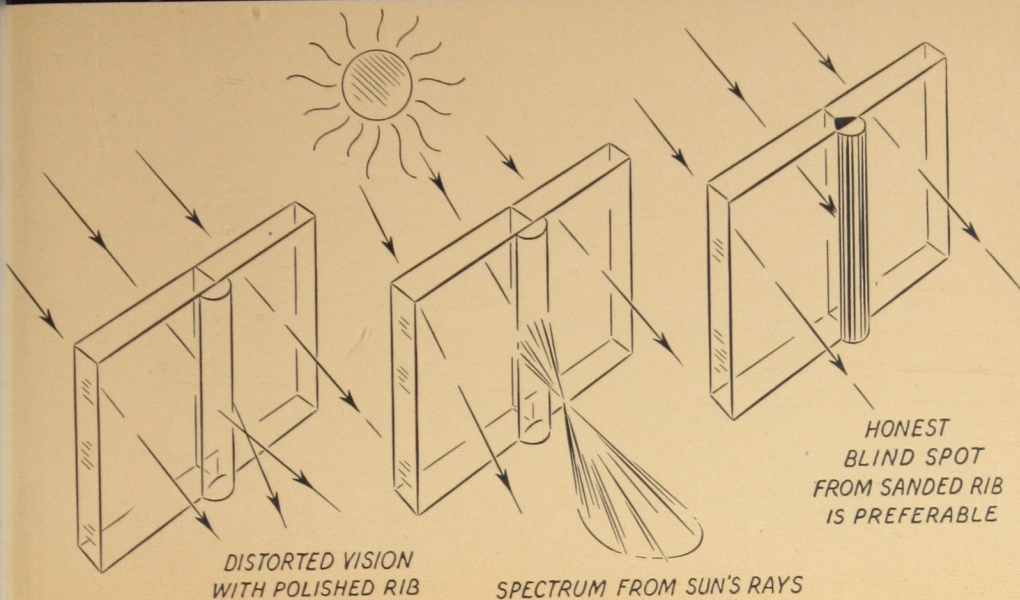
WRONG



OBSERVER

ALL LINES OF SIGHT NORMAL TO SURFACE

RIGHT



***In Fabricated Parts, Plexiglas
Reinforcing Ribs Should
Be Sanded or Machine Finished
Rather Than Polished***

Polishing of rib not only introduces an extra and unnecessary fabricating operation, but there is also danger that the observer's eye may not compensate for the great optical distortion and lens effect introduced by a polished transparent rib. Except in unusual cases, it is better to have an honest and obvious blind spot.

In addition, a thick polished Plexiglas rib may act as a prism, refracting the light source into a distracting spectrum of colors.

In Specifications, Define Critical Sighting Areas of Plexiglas Part, Particularly Areas Through Which an Optical Instrument Is to Be Sighted or Aimed. Do Not Sand and Buff These Areas

If the fabricator knows which sections of a Plexiglas part are critical optically,* he can devise suitable fabricating methods and inspect the finished part intelligently.

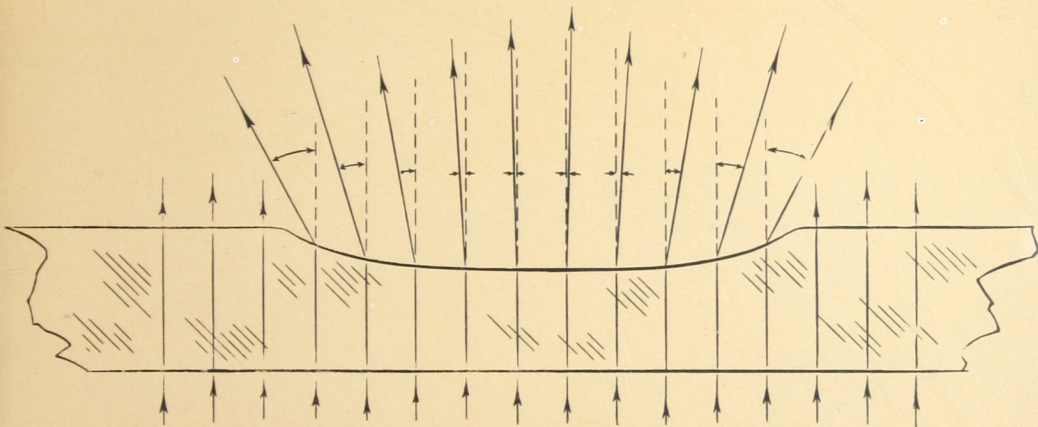
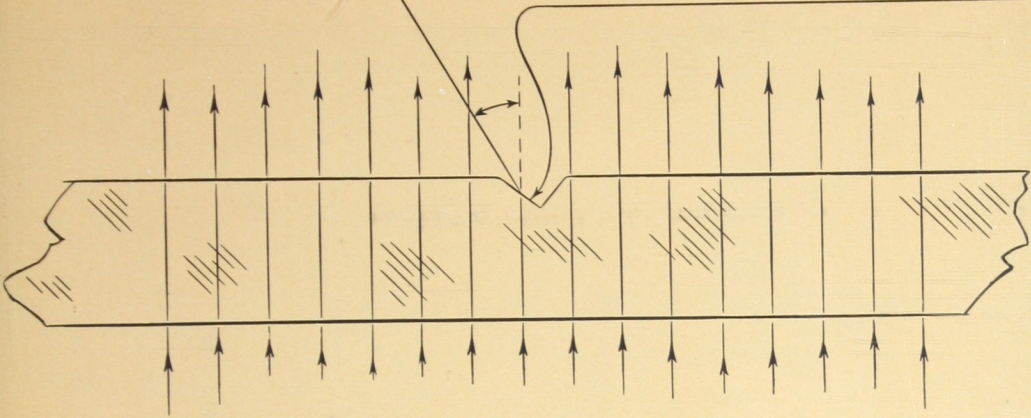
A few scratches affect only a minute area of such a panel whereas sanding and polishing, even if skillfully done, will introduce a slight wedge or lens effect. To the naked eye, this effect may not be important.

If a sighting device incorporating a lens is used, however, a sanded and polished area can introduce serious deviations in the line of sight; whereas a scratch would probably be barely visible.

Areas where optical qualities are of no consequence (sections to be covered by armor plate in aircraft parts or to be painted, or radio housings, et cetera) should also be designated so that the cost and manpower of polishing such areas can be eliminated.

* These areas must often be separate pieces of Plexiglas.

*SINGLE SCRATCH (GREATLY ENLARGED) CAUSES
DEVIATION OF SMALL BUNDLE OF RAYS ONLY*



*DEEP POLISHING TO REMOVE SCRATCH PRODUCES LENS AREA. THIS
CAUSES DEVIATION OF LARGE BUNDLE OF RAYS - THEREFORE DISTORTION*

SECTION 2

L I G H T



C O N T R O L *and* P I P I N G

The properties of Plexiglas give the product designer better *control* of light than he has ever had before. Light can be refracted, dispersed, intensified or directed by Plexiglas lenses and prisms. It can be “piped” through long lengths—and even around corners and curves—by Plexiglas parts.

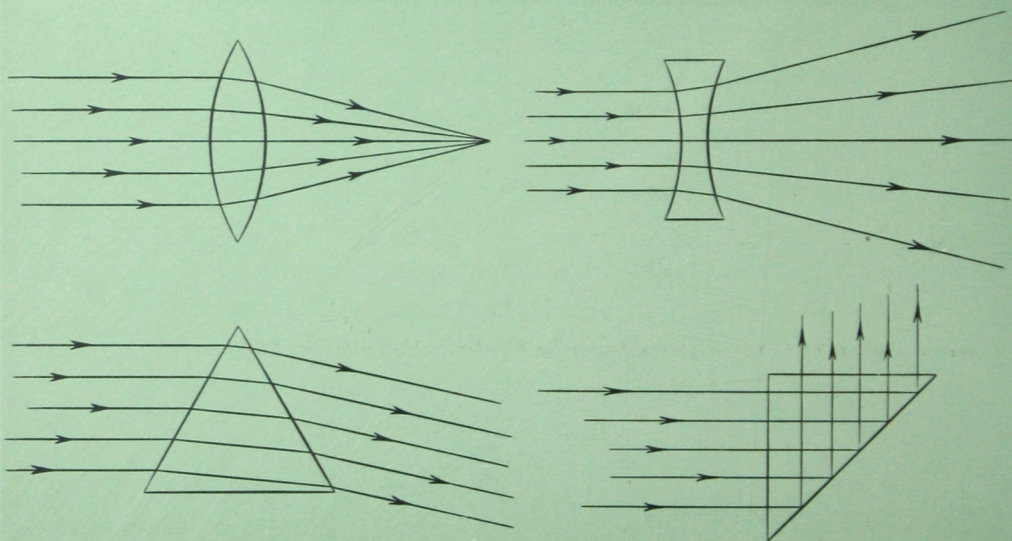
This “light piping” property can be used in many ways—medical instruments, inspection lights, signs, displays and dials—to mention a few examples.

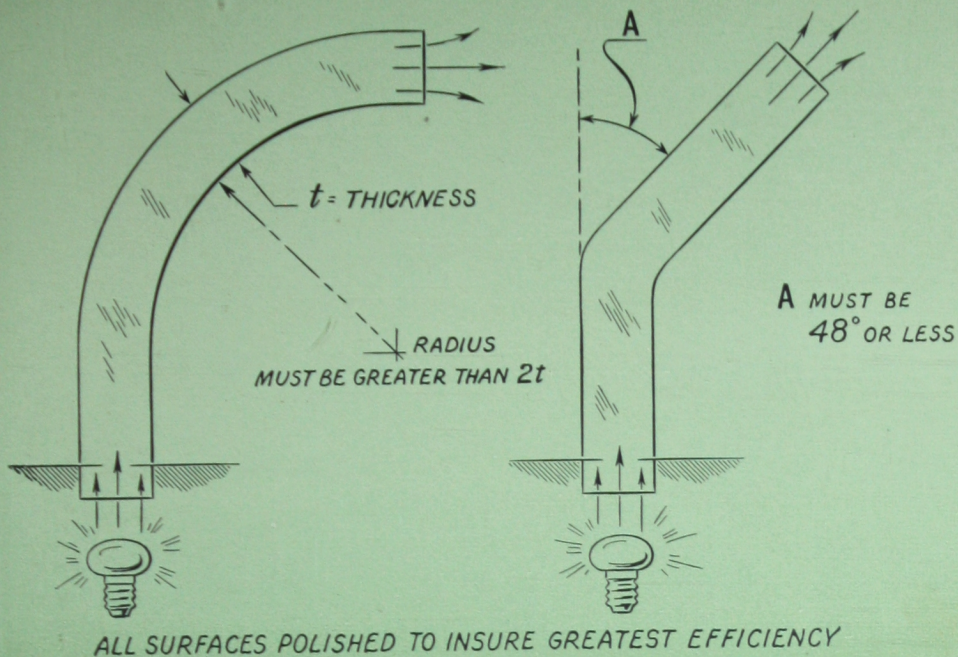
Theoretically, Plexiglas, because of its freedom from internal haze, could “pipe” light through many feet—in fact, an indefinite length. There are, however, certain practical limitations. First, such a possibility assumes an optically perfect surface which is not practical to produce in quantity in fabricating or in molding Plexiglas. Second, it also assumes that the surface be free of dust and dirt which might reduce the ability of Plexiglas to reflect light. Third, there is a limitation on the amount of light which can be reflected into the edge of the part.

For these reasons, it is difficult to establish a practical limit on the length of Plexiglas through which light can be efficiently piped. Molded automobile dials 12” and 14” long have been entirely satisfactory. Signs six feet long have also been used with excellent results.

*Take Advantage of the
Light-Directing and Magnifying
Possibilities of Prism and
Lens Shapes*

Magnifying and reducing lenses and prisms can be machined, molded or extruded from Plexiglas either as separate pieces or as part of a larger section. For example, a light-directing lens can be incorporated as part of a molded Plexiglas vacuum cleaner housing, or a magnifying lens can be incorporated in a Plexiglas dial cover molding. Obviously, this design saves assembly parts and time.





Do Not Plan to “Pipe” Light Around Sharp Curves or Angles

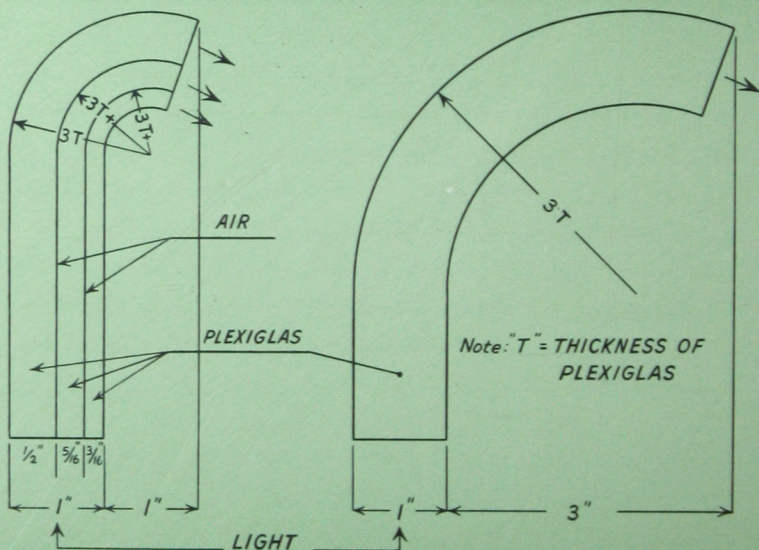
From the index of refraction of Plexiglas (value 1.49) it is possible to establish the limitation on the angle or curve around which Plexiglas can “pipe” light with high efficiency.

The limiting angle is 48° ; the limiting inside radius of curvature twice the thickness of the section. Plexiglas can “pipe” light around sharper angles and curves with greater efficiency than other types of material. For best effect, however, the limitations given above should be observed.

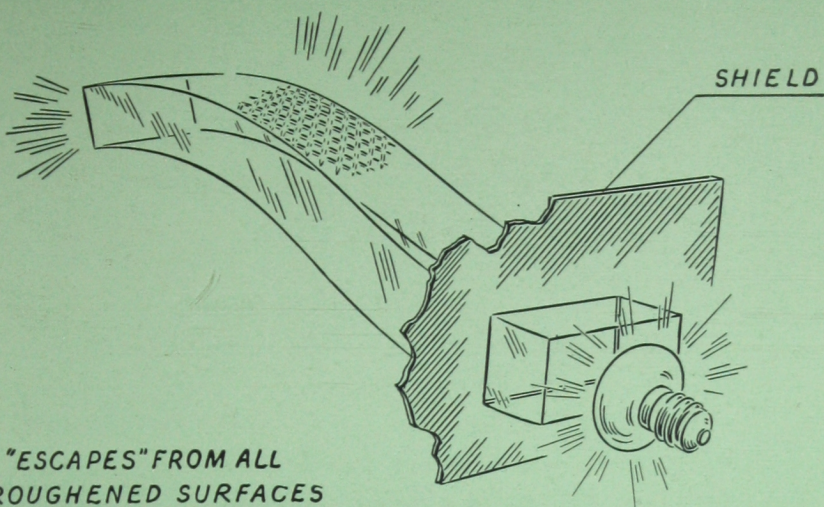
Use Multiple Layers of Plexiglas to Carry Light Around Sharp Curves

Design considerations may sometimes necessitate "piping" light around curves sharper than the recommended limit of curvature. This can be accomplished by assembling layers of Plexiglas, in graduated thicknesses, each sheet curved to an outside radius three times its thickness.

In assembling the individual curved sheets, care must be taken that the interior surfaces are completely clean and dry, to insure that there will be a continuous air interface between the layers, this being essential for satisfactory results.



LIGHT "ESCAPES" FROM ALL
ROUGHENED SURFACES



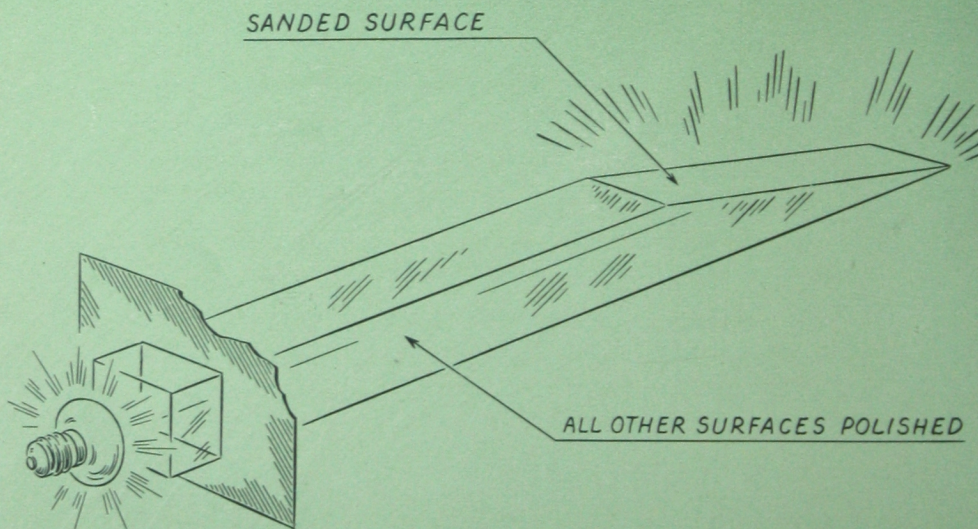
***Light Escapes Wherever the
Surface Is Broken by
Sandblasting or Engraving***

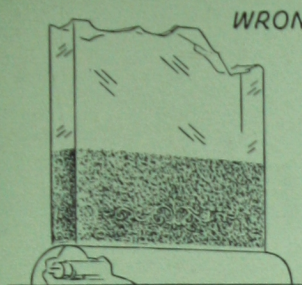
Since the light "piping" property of Plexiglas depends on the reflecting efficiency of its surface, it is possible to control the escape of light at various points simply by breaking the surface—by sanding, sandblasting, carving, engraving, or even painting — at the proper points. This effect is particularly useful in medical instruments, signs, dials and devices used to luminate inaccessible areas. Of course it can be used on curved as well as flat Plexiglas parts.

To Illuminate an Area, Taper as Well as Sand the Plexiglas Part

It is often useful, though not entirely correct, to think of light as travelling in straight lines or "layers" through a Plexiglas "pipe." Actually only a portion of the light does; the rest is carried by repeated reflections back and forth between the polished surfaces. The angles of reflection, however, are usually obtuse enough so that the "layer theory" is a sufficiently sound basis for many predictions.

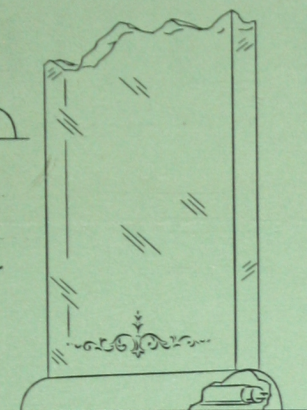
Using this theory, for example, the tapered area of the Plexiglas part shown above will interrupt successive layers of light, hence will be better lighted than a flat section that was only sanded. This design is desirable when a Plexiglas part is used to deliver general illumination to a given area.





A
LARGE SANDED AREAS
NEAR LIGHT SOURCE RE-
DUCE AMOUNT OF LIGHT
"PIPED" TO REST OF SHEET

RIGHT



B
POLISHED SURFACES,
SMALL LETTERING OR
OPEN DESIGNS OCCUPYING SMALL AREAS NEAR LIGHT
SOURCE PERMIT "PIPED" MORE LIGHT TO REST OF SHEET

WRONG



A
DESIGN ENGRAVED
ON OUTSIDE OF
SOLID ROD IS
ILLUMINATED
ONLY SHORT
DISTANCE

RIGHT



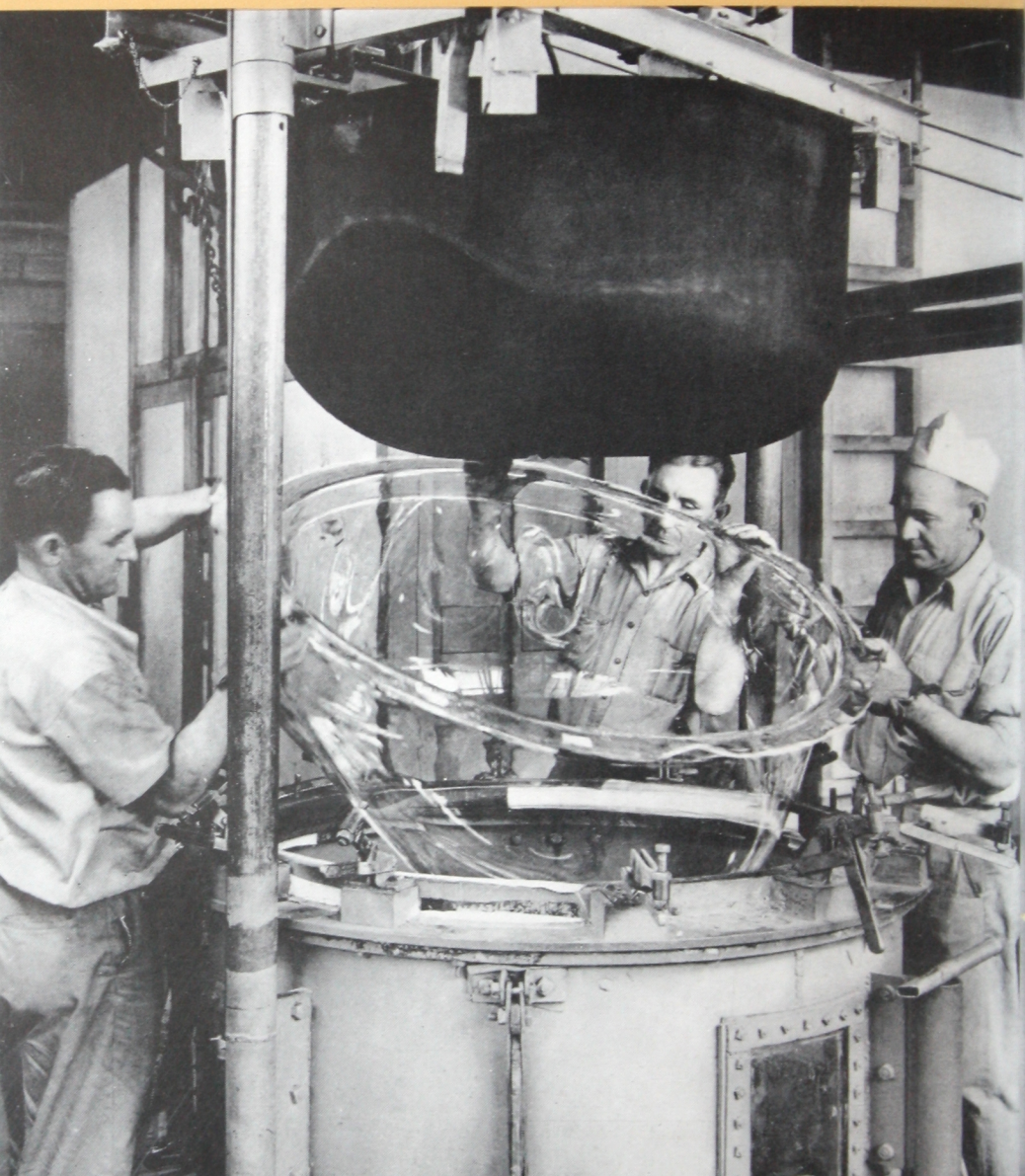
B
SHEET IS ENGRAVED
THEN FORMED INTO TUBE

***For Most Efficient Light Piping,
Areas Near Light Source
Should Be Polished***

If large areas near the light source are sanded—especially areas on both surfaces—most of the light escapes at such areas and little is piped to the rest of the sheet. Therefore, only small lettering or very open designs—preferably only on one surface—should be used near light source, if the rest of the design is to be illuminated efficiently.

In the case of designs involving round stock, cylinders are preferable to solid rod since the former have almost twice as much surface area. Designs can be engraved on flat sheet which can later be heat-welded into cylinders with the design on the inside.

SECTION 3... FABRICATING



C O N S I D E R A T I O N S

There is almost no limit to the designs which can be executed in sheet Plexiglas.* It can be sawed, drilled, machined, threaded, routed and swaged. In addition to all of these operations, which were borrowed from the wood and metalworking industries, Plexiglas can also be formed to almost any curvature while it is hot (220° F. to 300° F.). After cooling to room temperature, Plexiglas will retain this curvature.

As with all materials, however, mass production imposes certain logical limitations on what can be fabricated economically from Plexiglas sheet. Some of these limitations and some suggestions for simplifying fabrication are outlined on the following pages.

* **NOTE TO DESIGNERS**

Plexiglas has proved an ideal material for the fabrication of design or demonstration models. It is as easy to machine as any soft metal, and is free from the grain which complicates model-making in wood.

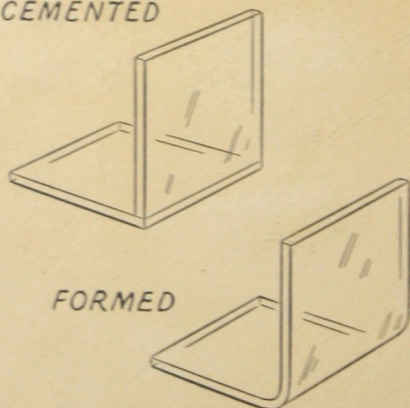
*Avoid Cemented Joints in
Production Design of Parts
Where Appearance Is a Factor*

With care, practice and special techniques, it is possible to produce a cemented or heat-welded joint approximating Plexiglas itself in strength and transparency. However, it is difficult and expensive to produce a great quantity of cemented joints which do not have included bubbles, dirt or other defects.

Wherever possible, therefore, avoid cementing. For example, take advantage of the possibility of forming Plexiglas to avoid cemented corners.

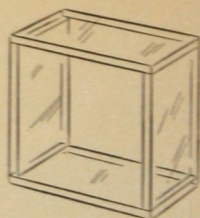
If a cemented joint is used—particularly in decorative items—consider making an honest, visible joint by adding a dye, pigment or metal particles to the cement rather than attempting a perfect transparent bubble-free joint. A colored joint may add to the appearance of the finished piece. Alternatively, have some engraved or molded design follow—and obscure—the joint.

CEMENTED

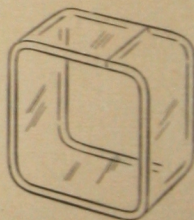


FORMED

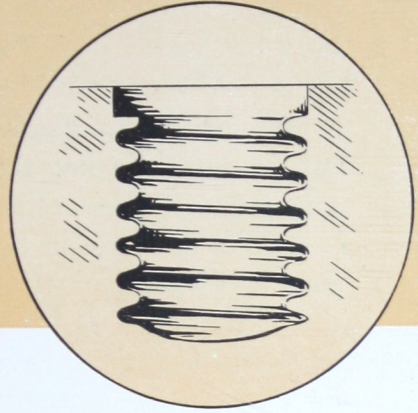
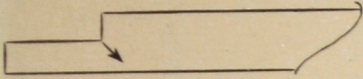
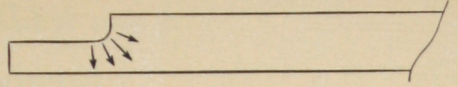
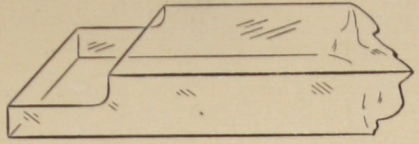
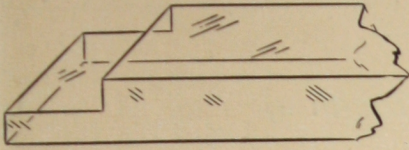
CEMENTED



FORMED



RIGHT



WRONG

In Routing or Threading Plexiglas Avoid Sharp Points or Corners

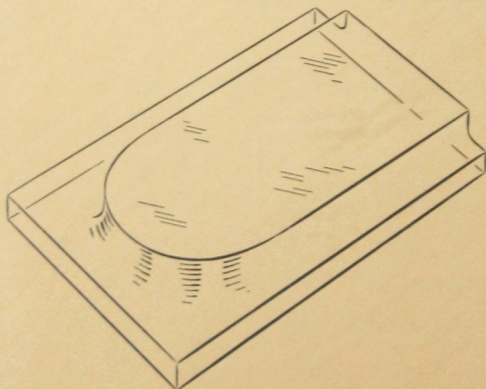
Laboratory tests have shown that a piece of Plexiglas with a “V” shaped notch has only 65% of the impact strength of a sample with a round bottom notch. Therefore, specify a radius on all routs and fillets and avoid sharp “V” apexes in threading and tapping Plexiglas. This is a good rule to follow in designing parts to be made of any plastic material.

Keep Width and Depth of Routing Uniform

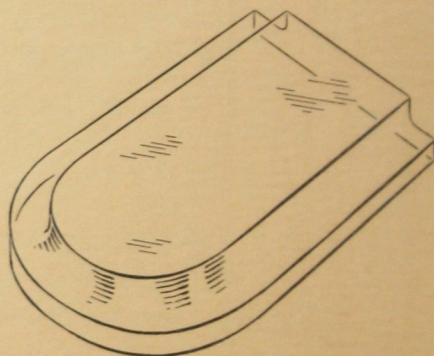
Part "B" shown below can be put through a routing machine in a single, simple operation provided the internal corner radius is concentric with external corner radius. On the other hand, part "A" is difficult to fabricate in quantity, particularly if the panel is curved.

PART A

*VARYING ROUT WIDTH
WRONG*



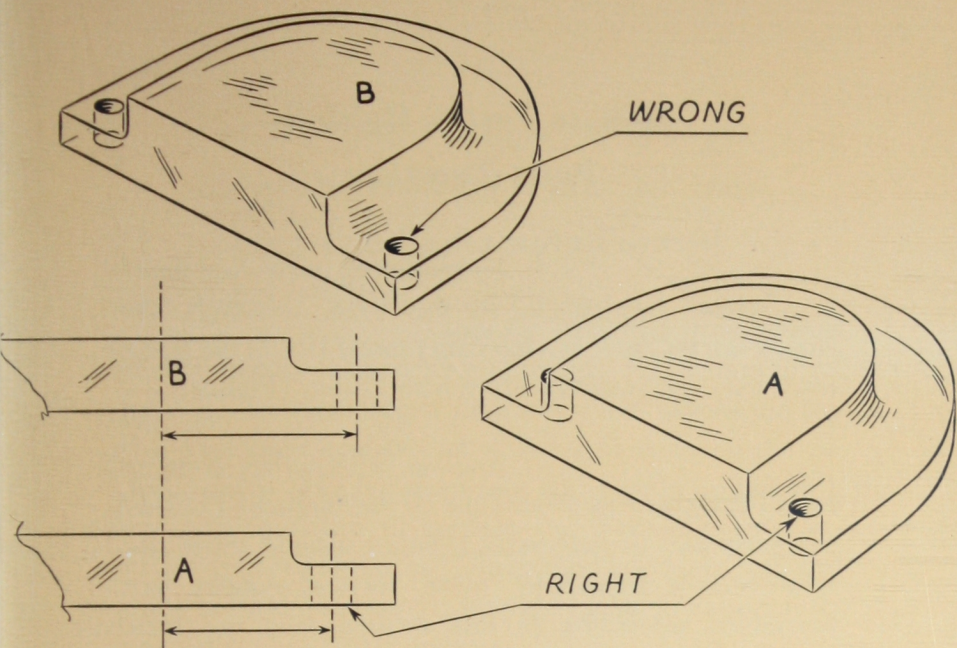
RIGHT



PART B

UNIFORM

ROUT WIDTH



***Where Routed Panels Are Mounted
with Bolts or Rivets, Keep Holes
Close to Thick Portion of Panel.****

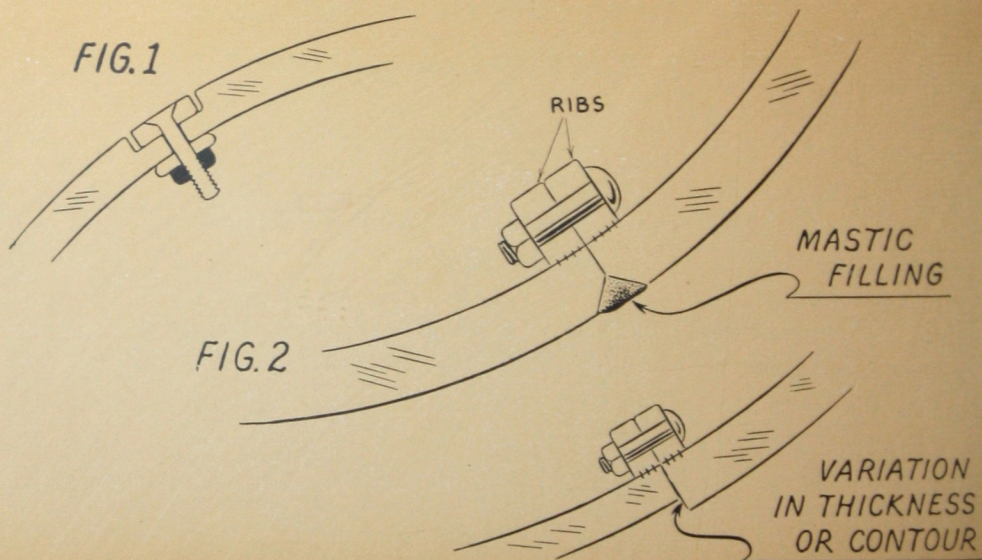
As shown in "A," a hole close to the full thickness minimizes any bending moment tending to break the panel along the rout.

* Drilling holes in Plexiglas is not recommended but where necessary precautions given in "Plexiglas: Methods of Installation" should be followed.

How to Fasten Multiple Parts Together

1 By mounting individual panels in a metal framework. In this case, relatively thin panels can be used; but too many metal ribs in the framework may seriously interfere with vision. (Figure 1.)

2 Another alternative is to cement Plexiglas ribs around the circumference of individual parts and to bolt parts together around these ribs. Because it is difficult to “mate” formed sections, parts assembled according to this method may not match exactly. Mating parts may also vary in outside contour due to thinning out of material in deep draw forming. If a smooth, outside contour is necessary, suggest chamfering both edges and filling “V” shaped opening with an approved mastic compound. (Figure 2.)



*Use "Surface Tension" Shapes for
Three-Dimensional Parts so that
They Can Be Vacuum-Formed*

Properly designed three-dimensional parts can be made from Plexiglas by vacuum forming, i. e., by clamping a hot, soft sheet across the top of a vacuum chamber and drawing it down to the required depth. The hot sheet does not come in contact with any form to distort its surface and therefore shows excellent optical properties. The method is simple, fast, and requires little manpower. It could be made almost fully automatic.

Varying the shape of the pot opening and clamping ring—in one or two planes—permits production of a large number of shapes. Almost by definition, these shapes, which are called surface tension shapes, are streamlined and well proportioned.

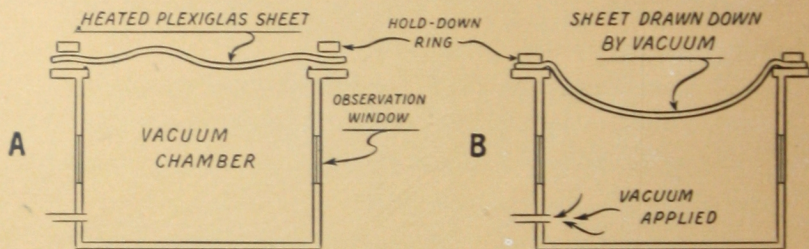
It is necessary to allow for thinning out of the material. As a rough guide, a 22" diameter hemisphere (11" deep) thins out to one-third of its original thickness at the point of deepest draw.

Modification of surface tension shapes can often be obtained by the "vacuum snap-back" forming process. After a sheet has been drawn into a vacuum chamber, as above, a male form of the inside contour of the required part is lowered inside the Plexiglas "bubble." The vacuum is then released slowly; the still hot Plexiglas sheet tends to resume its flat shape and "snaps back" slowly around the male form. Needless to say, the form should

be constructed and the part designed with enough side draft or clearance so that the form can be removed easily from the part.

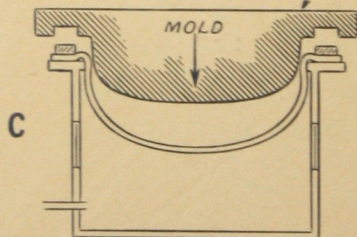
Since the Plexiglas sheet will not "snap-back" into reverse curves, fluting, reeding and square corners, avoid such contours in designing the part.

Snap-back forming can be useful in forming the base and four sides of a box or housing or cabinet in one operation. Inherent in both vacuum and snap-back forming is an integral flange at least $\frac{3}{4}$ " wide where the sheet is clamped over the vacuum chamber. Since the contour of this flange can be held to very close tolerances, it provides an excellent means of mounting or attachment.

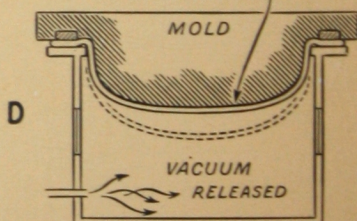


VACUUM FORMING
SHAPE DETERMINED BY SHAPE OF CHAMBER OPENING

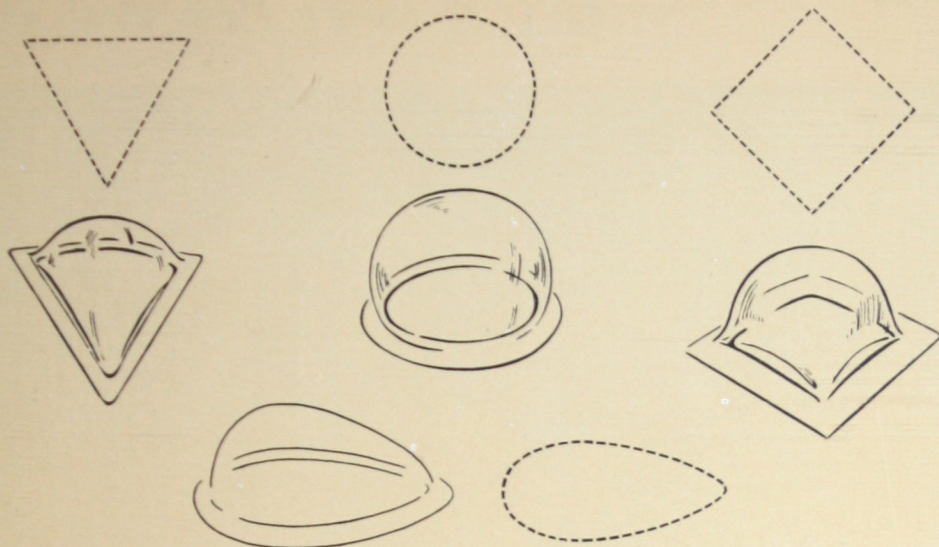
MALE FORM LOWERED INSIDE "BUBBLE"
FORMED BY VACUUM - (FIGS. A AND B)



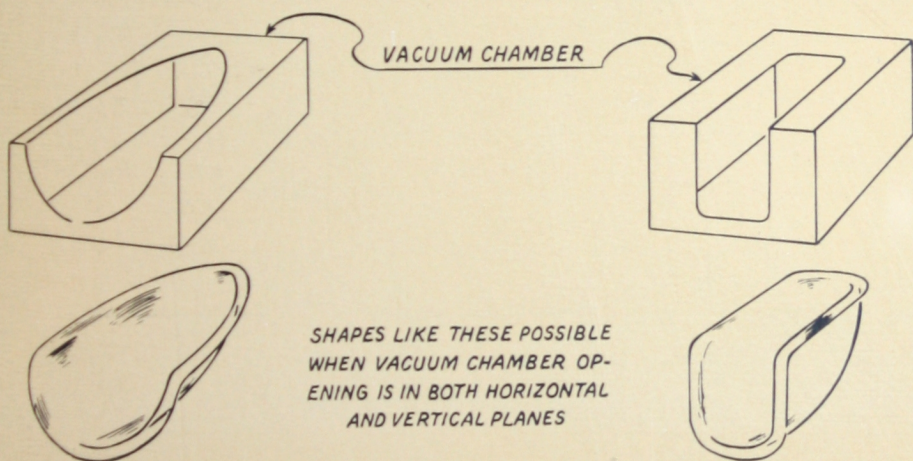
AS VACUUM IS RELEASED
PLEXIGLAS "SNAPS BACK" TO
FIT MALE MOLD



VACUUM SNAP-BACK FORMING
SHAPE DETERMINED BY MALE MOLD



VARIETY OF VACUUM CHAMBER OPENINGS, SHOWN BY DOTTED LINES, INDICATES SOME OF THE "SURFACE TENSION SHAPES" POSSIBLE IN VACUUM FORMING



SHAPES LIKE THESE POSSIBLE WHEN VACUUM CHAMBER OPENING IS IN BOTH HORIZONTAL AND VERTICAL PLANES

SECTION 4 . . .

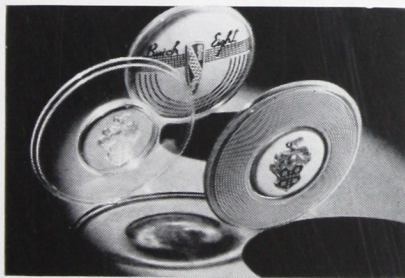


MOLDED PARTS

In the manufacture of large quantities of identical parts, compression or injection molding often offers many advantages over fabrication. Within certain limitations of size and shape, molding is faster, usually cheaper, and often permits closer dimensional control than fabrication.

Most important, however, is the fact that by intelligent mold design, finishing and assembly operations can be simplified or eliminated. To be sure, these features may increase the cost of the mold to the point where they are not economical; but more often they make savings which more than justify higher mold or material costs.

No attempt is made here to suggest size and location of gates, runners and sprues. This is a matter better left in the hands of a competent custom molder who is familiar with the requirements of acrylic molding powders.



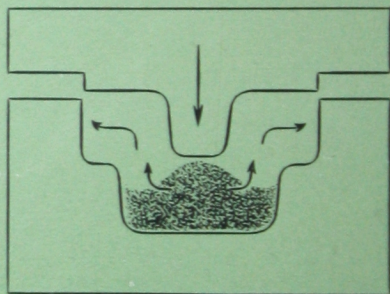
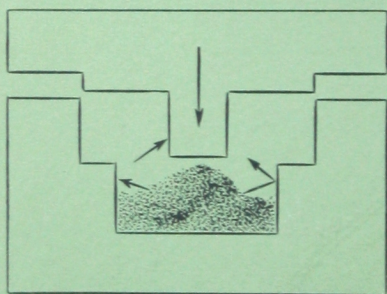
Color applied to back of clear moldings gives three-dimensional effect (Cardinal)

Keep Cross Section as Uniform as Possible. Favor Rounded Rather Than Sharp Corners

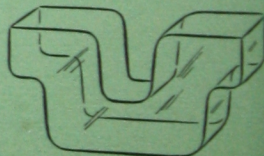
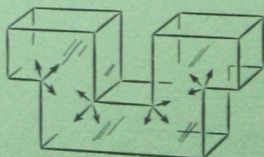
This recommendation applies to major dimensions and contours and is based on a number of factors:

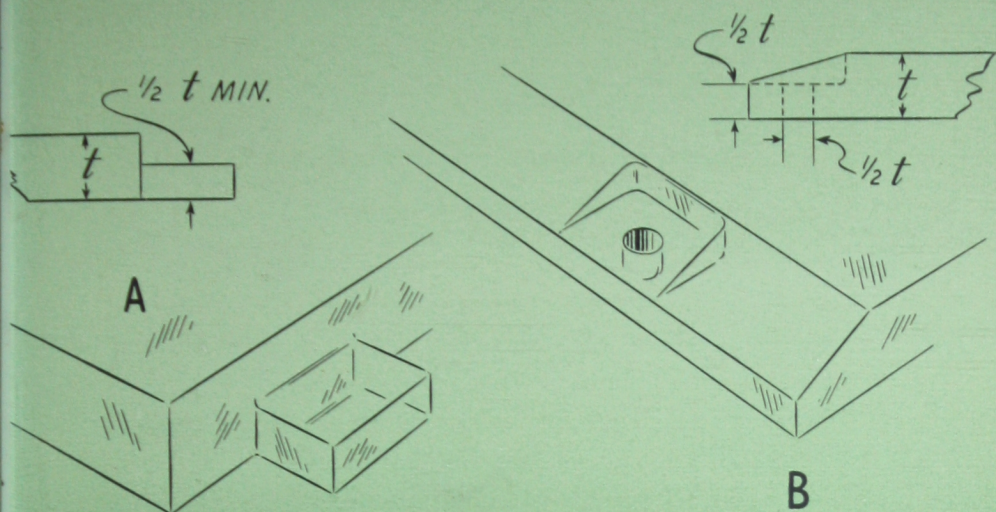
- (a) Molds with sharp corners are usually more expensive.
- (b) If part is to be subjected to flexural stress, a filleted corner is far less apt to crack than a sharp one.
- (c) The flow of material in the mold will be better with rounded corners. There is less danger of sticking if the corners are rounded.

Sharp edges are desirable, however, for markings in Plexiglas dials and nameplates, to facilitate wiping in pigment (see page 48).



PREFERABLE





Mold in Mounting Rims or Lugs to Save Assembly Parts and Time

Mounting rims or lugs should be as substantial as possible, particularly if the Plexiglas molding is to be subject to impact or flexural stress. They should be at least half the thickness of the molding, and as long and numerous as possible, or preferably continuous.

A convenient modification is to make the mounting lug a cut-out step in a chamfered edge, as shown in figure B.

Lugs should be filleted into body of molding to avoid sharp corners.

A mounting hole may be placed in the lug, provided sufficient material is allowed all around it. This rim around the hole should be at least as thick as the lug itself.

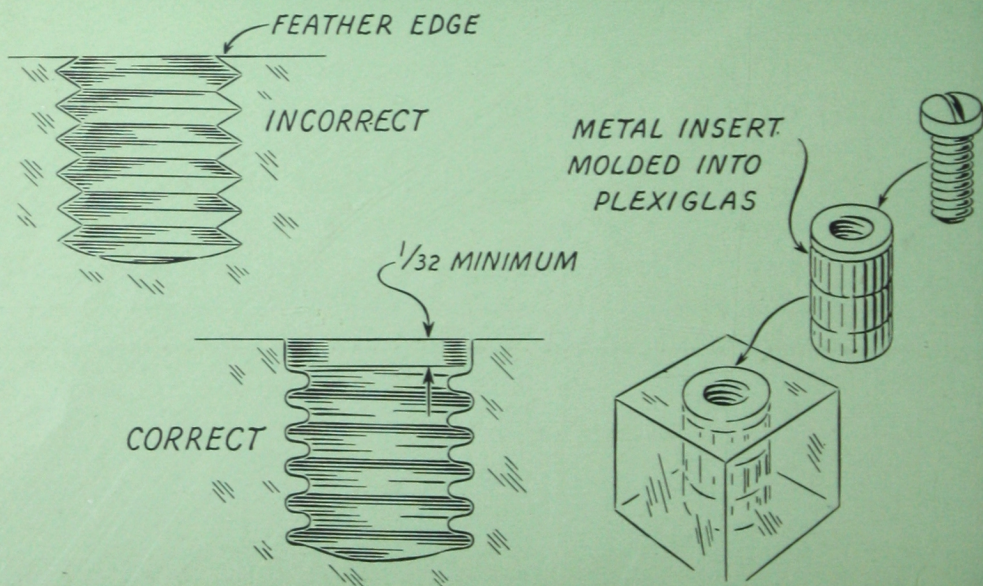
Mold in Screw Threads to Save Assembly Time

Threads incorporated in the molded Plexiglas part can save assembly time but increase the cost of the mold. If this increase is not justified by saving in assembly, it is possible to tap a thread in Plexiglas moldings. In the latter case, mold in a countersink as a guide to the tapping die.

"Molded in" threads should be coarse and heavy with rounded apexes to reduce danger of cracking. Do not start thread at surface of the molding. Allow at least $1/32''$ to eliminate feather edge.

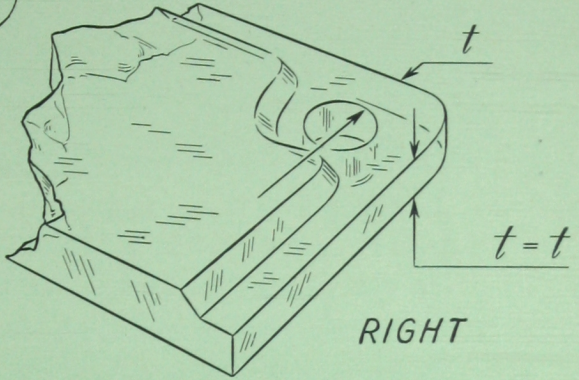
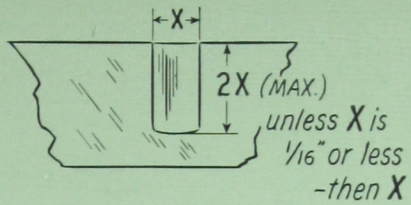
It is not practical to mold threads into the part except for hole diameters of $1/4''$ or more.

If the part will be frequently disassembled it is probably preferable to use metal inserts in the part. (See page 43 for details.)



WRONG

DIFFICULT
TO MOLD



RIGHT

Do Not Place Mounting Holes Near The Edge of Molding

For greatest strength, mounting holes should not be less than the thickness of the Plexiglas piece and preferably farther away from the edge of a molding to allow for flow of material around the pin in the mold.

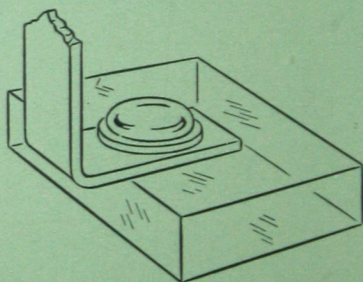
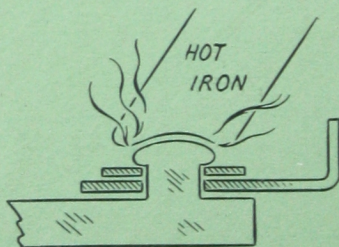
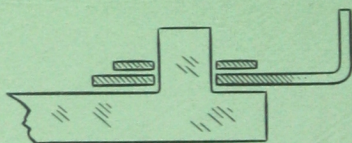
If possible, the hole should pass entirely through the part so that core pins can be supported in both sides of the mold. A good design rule is that the depth of the hole should not be more than twice the diameter of the hole. Small holes ($\frac{1}{16}$ " or less) should not be deeper than the diameter of the hole.

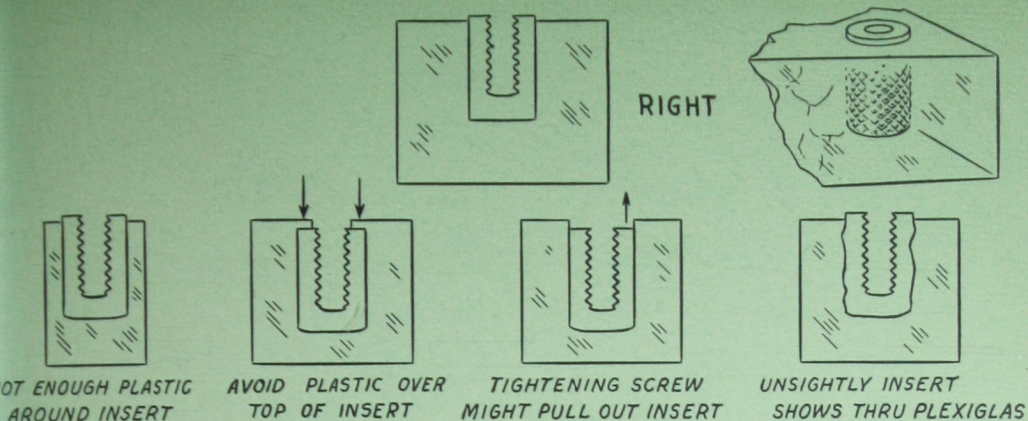
Use Molded Plexiglas "Rivets" for Mounting to Metal.

It is possible to incorporate short projecting lugs in the molded Plexiglas part which can later be sealed over by heat and pressure.

This process can be fast and almost automatic. The method cannot be used, of course, if the assembly is to be taken apart.

It is also possible, by the use of longer lugs, to use "speed nuts" directly on the head of the molded Plexiglas lug.





Use Metal Inserts to Speed Mounting and Improve the Usefulness of Part

When designing an insert, allow for sufficient plastic material to give the insert solid anchorage, to permit flow of the material around the insert and to accommodate differences in expansion and contraction between metals and Plexiglas.

Particularly in compression molding, but also in injection molding, make the insert short and sturdy enough so that it will not be broken, bent, or dislodged by the flow of material. The proportion of depth to diameter should not be more than 2:1.

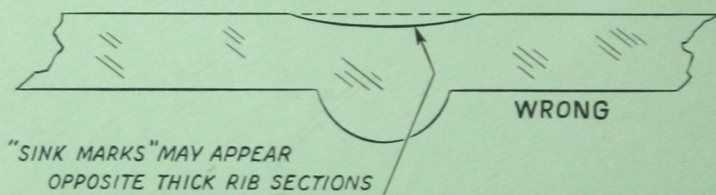
Inserts should either project above the surface of the plastic or at least be flush with it. A narrow lip of plastic between an insert and a bolt for example, is subjected to high stresses if the bolt is tightened.

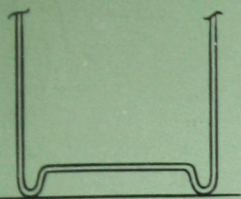
Remember that Plexiglas is transparent, and the design of the exterior of the insert should be considered for appearance's sake.

If Ribs Are Used to Reinforce Flat Area, Break Opposite Surface with Fluting or Other Decorative Device

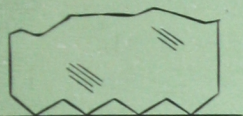
During cooling, molded sections contract and shrink roughly in proportion to the volume of material at any given point. If the volume varies, as in the case of a rib reinforcing a flat area, excessive contraction of material will show up—not on the domed surface of the rib, but on the flat (presumably exterior) surface.

Such “sink-marks” can often be eliminated by exact control of molding cycle; but such critical control is not always possible or economical. It is therefore preferable to break the Plexiglas surface opposite the rib by fluting or other decorative device on which sink-marks will not appear.

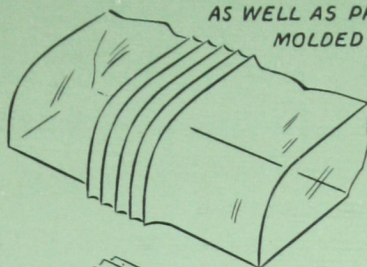




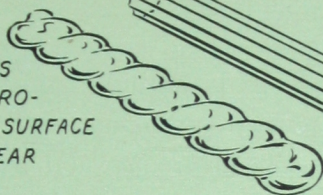
BASES SHOULD BE
REEDED, BEADED,
FLUTED ETC. AT
POINTS OF CONTACT



MOLDED FINS STRENGTHEN
AS WELL AS PROTECT
MOLDED PARTS



ROPE PATTERNS
FLUTING ETC. PRO-
TECT GREATEST SURFACE
AREAS FROM WEAR



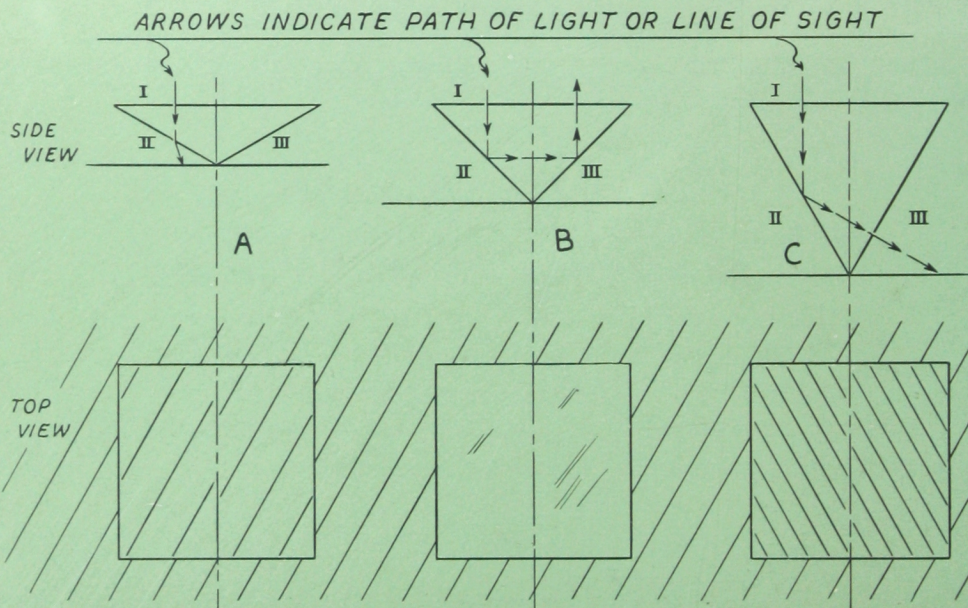
Give Special Surface Treatment to Parts Which Will Be Subjected to Scratching in Service

To take advantage of the brilliant sparkle of Plexiglas moldings, break the surface into a number of polished facets which will catch and reflect the light in bright patterns.

Rope effects, fluting, reeding and other surface treatments are not only attractive in themselves, but also reduce the visibility of any slight surface scratches the molding may receive if given rough handling.

How to Obtain Maximum "Glitter" in Faceted Plexiglas Molding

Refrigerator door handles, radio dials and bases, door knobs, trays, automotive and electrical appliances—all are applications where the gemlike brilliance and lustre of faceted Plexiglas can add new interest and eye appeal. The sparkle of Plexiglas can be accentuated by cutting or molding facets into the back surface. The following directions explain how almost any desired degree of brilliance can be achieved in this way.



If prism angle is less than 42.2° , light hitting surface I (Sketch A above) vertically is transmitted (and refracted) through surface II. Pattern on a horizontal plane touching prism apex is distorted by refraction, but visible.

If prism angle is between 42.2° and 45.9° light hitting surface I vertically is efficiently reflected from surfaces II and III back out through surface I. Pattern on a horizontal plane touching prism apex is not visible (Sketch B).

If prism angle is between 45.9° and 74° light hitting surface I vertically reflects from surface II and is refracted through surface III. Pattern on a horizontal plane touching prism apex is visible but reversed, being a reflected image (Sketch C).

Assuming the three prisms are usually viewed from the top, approximately vertical to the front surface, designs B and C will give more "glitter" than A. The choice between B and C will depend on the conditions under which the molding will be used. If, for example, only the top surface is visible and the rest of the prism encased in an opaque mounting, B would have more glitter than C. Otherwise, however, C would appear more brilliant since it picks up and reflects light from both sides as well as the top of the prism. Most side light would ordinarily be reflected from surface II or III of prism B.

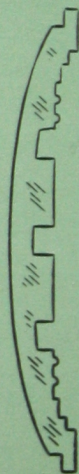
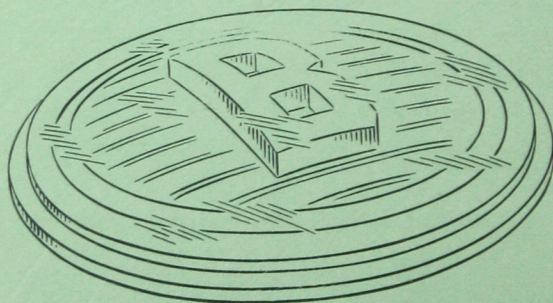
Three-Dimensional Moldings

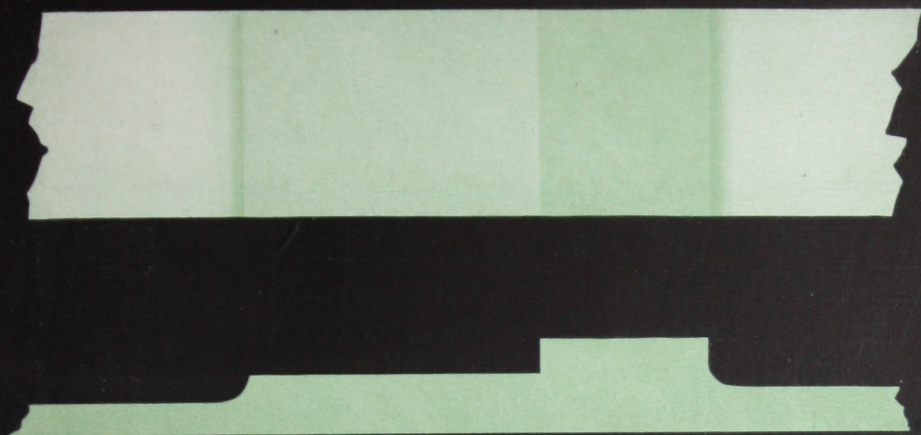
The crystal-clarity of Plexiglas is used indirectly in three-dimensional moldings. The front surface of the molding is smooth; a seal, trademark or other marking is molded into the back in different depths. When appropriate colors are wiped into these markings and a background color applied, an impressive three-dimensional effect is obtained when the Plexiglas molding is viewed from the front.

Precautions: (1) The depth of letters, seals, et cetera, should *not be over one-half of total thickness* of molding to permit proper flow of material.

(2) Paints and pigments which do not harm Plexiglas should be used. In general, the four-hour enamels are satisfactory; solvent base lacquers are not.

This type of molding offers obvious possibilities for nameplates, jewelry, compacts, containers and other decorative parts.





*Take Advantage of Delicate Tints
Possible in Plexiglas, or Jewel-Like
Depth of Darker Colors*

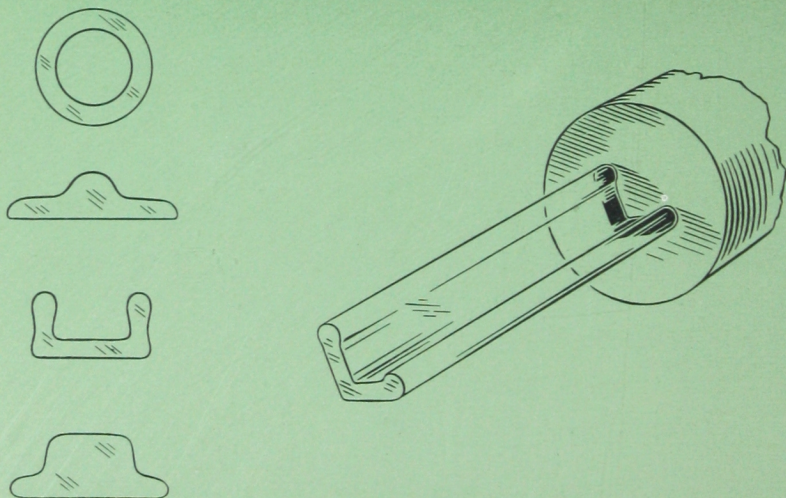
Because of its inherent clarity, Plexiglas can be made in a wide range of colors. The light tints are very delicate, and excellently suited to hair brushes, cosmetic containers, compacts and ladies' accessories. The darker shades have rich depth for use wherever stronger colors are indicated.

Interesting multi-tone effects are possible, particularly with tints, by designing Plexiglas parts of varying thicknesses. Thicker sections are deeper in color than thin sections.

***For Long Parts, Consider Keeping
Profile Uniform so that Section
Can Be Extruded***

Continuous extrusion of Plexiglas is a fast and economical method of production, often possible where the design of the cross section or profile is uniform. In extrusion, molding powder is heated and forced by a screw thread through a die opening. The product, available in almost any length, assumes approximately the same cross-section as the die.

It is sometimes difficult to extrude thin fins in combination with thick sections, and there are some limitations on the included area of the profile. These factors are best discussed with an experienced extrusion molder before the design is frozen.



APPENDIX

	PAGE
Availability Data	52
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Optical Properties	54
Mechanical Properties	54
Chemical Properties	55
Electrical Properties	55

SPECIFICATIONS

Plexiglas has fully met and passed the following specifications:

U. S. Army: "Sheet, transparent" Grade A—94-12014C.

Army-Navy: Plastic Sheet, Acrylic Base—AN-P44.

U. S. Navy: Bureau Eng. & Rep.—Methacrylate Glazing—33-M-1.

U. S. Navy: Bureau of Ships—Plastic Dial Covers—17-P-8 (INT.) (except paragraph E-1-g).

PLEXIGLAS SHEETS

Sizes and Colors

Standard Thicknesses and Dimensions—

Thickness	Thickness Tolerance	Thickness	Thickness Tolerance	Thickness	Thickness Tolerance	Thickness	Thickness Tolerance
.060	± .010	.125	± .015	.220	± .022	.375	± .038
.080	± .010	.150	± .015	.250	± .025	.500	± .050
.100	± .012	.187	± .019	.312	± .031		

Available in these sizes (inches):

36 x 48		36 x 60		40 x 50	
6 x 12	12 x 48	18 x 60	24 x 60	30 x 36	36 x 36
12 x 12	12 x 60	20 x 50	24 x 24	24 x 36	18 x 36
12 x 18	18 x 18	24 x 24	24 x 36	12 x 48	12 x 60
12 x 24	18 x 24	24 x 36	12 x 36	12 x 48	12 x 60
12 x 36	18 x 36	24 x 48	12 x 48	12 x 60	12 x 60

Larger Standard Sizes in Thicknesses from .100 to .500:

36 x 72	48 x 60	60 x 72
48 x 48	48 x 72	67 x 79
	53 x 80	

Also thicknesses 6.25 to 2.000 in 1/8" increments in these sizes:

6 x 12	12 x 36	24 x 24	36 x 36
12 x 12	12 x 48	24 x 36	36 x 48
12 x 24	20 x 50	24 x 48	40 x 50

Colors—Red, Ruby Red, Amber, Yellow, Green, Dark Green, Blue, White Translucent. Visual color match attempted in special cases on orders for 100 square feet or more of any one color.

PLEXIGLAS MOLDING POWDERS

Grades and Colors

Grades for injection and compression molding and for extrusion. Special formulae for increased heat resistance.

Colors: Red, Amber, Yellow, Green, Aquamarine, Blue, Violet, White Opaque, Brown Opaque, Black Opaque. Visual color match attempted on minimum initial order of 500 pounds and on subsequent minimum orders of 200 pounds. No extra charge for colored material.

FURTHER INFORMATION.....

The Rohm & Haas Company maintains a staff of trained technical representatives to assist in the development of new PLEXIGLAS products and parts. The services of these men, technical data from our physical testing laboratories and the benefits of our own fabricating experience are available on request.

NEW YORK 18, NEW YORK

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Riverside 6593

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Wabash 3076

DETROIT 2, MICHIGAN

819 Fisher Building
Madison 1500

ST. LOUIS 1, MISSOURI

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812 Olive St.
Garfield 6648

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Crystal Glass & Plastics, Ltd.
56 Boulton Ave.
Toronto, Canada

H O M E O F F I C E :

ROHM & HAAS COMPANY
WASHINGTON SQUARE
PHILADELPHIA 5, PA

Table of Optical Data

Property	PLEXIGLAS Sheets*	Molded PLEXIGLAS*
Light Transmission	90-92%	90-92%
Haze	1-3%	3-10%
Refractive Index N_D	1.488-1.489	1.48-1.50
Dispersion N_F-N_C	0.008	0.008
Effect of Sunlight.....	Very slight	Very slight
Effect of Age	Very slight	Very slight
Optical Density	0.036	0.036
Transmissible Wave Lengths	3,600 Å to 10,000 Å	3,600 Å to 10,000 Å
Permanence	1% trans- mission loss in 200 sunshine hrs.	1% trans- mission loss in 200 sunshine hrs.

Table of Mechanical Data

Property	PLEXIGLAS Sheets*	Molded PLEXIGLAS*
Specific Gravity (25° C.)	1.18	1.18-1.19
Tensile Strength (psi).....	5,800-8,800	4,000-6,000
Elongation at Break.....	min. 2%	1-5%
Hardness—Mohs	2-3	2-3
Rockwell	M-70	M-70
Brinell (500 kg., 10 mm. ball).....	18- 20	18-20
Flexural Strength (psi).....	13,000-15,000	10,000-15,000
Compressive Strength (psi)	13,000-15,000	10,000-15,000
Impact Resistance (ft. lb.)..... A.S.T.M. Charpy, unnotched bar	3-4	2-4
Modulus of Elasticity (psi)	$3-4 \times 10^5$	$3-4 \times 10^5$
Coefficient of Expansion	$8 \times 10^{-5}/^\circ \text{C.}$	$8-9 \times 10^{-5}/^\circ \text{C.}$
Water Absorption (max. weight gain 24 hrs.)	0.6%	0.6%

* Since PLEXIGLAS is a thermoplastic, its properties will be found to vary with temperature. Values given apply for 25°-30° C. (77°-86° F.).

Table of Chemical Data

Solution	Per Cent Weight Gain (192 Hrs. at 25° C. (77° F.))	
	PLEXIGLAS Sheets*	Molded PLEXIGLAS*
30% Sulphuric Acid	0.1	0.6
3% Sulphuric Acid	0.5	1.0
10% Hydrochloric Acid	0.5	0.7
10% Sodium Hydroxide	0.4	0.8
1% Sodium Hydroxide	0.5	1.0
10% Nitric Acid	0.9	0.9
5% Acetic Acid	0.8	1.0
100% Oleic Acid	0.0	0.0
2% Sodium Carbonate	0.8	1.0
10% Sodium Chloride	0.8	0.9
10% Ammonium Hydroxide	0.7	0.9
3% Hydrogen Peroxide	0.8	1.0
100% Distilled Water	0.9	0.9
Gasoline	0.2	0.2
95% Ethyl Alcohol	24 (softened, made flexible)	Dissolved
50% Ethyl Alcohol	6 (softened, made flexible)	Dissolved
Acetone, Ethyl Acetate, Ethylene Dichloride Carbon Tetrachloride, Toluene.....	Dissolved	Dissolved

* All concentrations given in % by weight in distilled water. A change in weight of 1% or less is considered negligible.

Electrical and Thermal Data

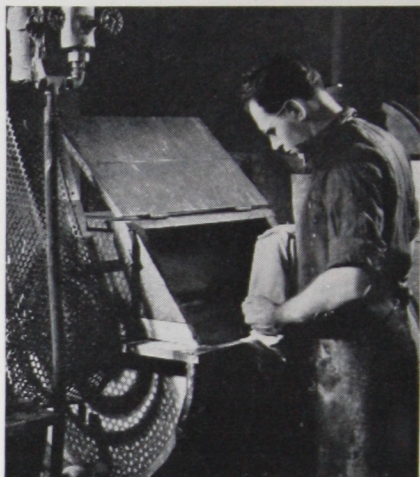
Property	PLEXIGLAS Sheets*	Molded PLEXIGLAS*
Dielectric Constant:		
60 cycles	3.4-3.6	3.4-3.6
1,000 cycles	3.2-3.4	3.2-3.4
1,000,000 cycles	2.5	2.5
Dielectric Strength, volts per mil, 60 cycles:		
short time test	500	500
One-minute step-wise test.....	400	400
Power Factor, %—A.S.T.M. Method D-150-36T:		
60 cycles (Bridge method)	5-6	5-6
1,000 cycles (Bridge method)	5-6	6-7
1,000,000 cycles (substitution method) ..	2.5	2-3
Volume Resistivity (ohms/cm. ³)	over 10 ¹⁵	over 10 ¹⁵
Thermal Conductivity: 10 ⁻⁴ cal./sec./sq. cm./° C./cm.	4-6	4-6
Resistance to Heat (° F. cont.)	140-160	120-140
Specific Heat (cal./° C./gm.)	0.35	0.35

* Since PLEXIGLAS is a thermoplastic, its properties will be found to vary with temperature. Values given apply for 25°-30° C. (77°-86° F.).

PLEXIGLAS

*is only one
of many products of Rohm & Haas research . . .*

Representative of the broad scope of Rohm & Haas research is DITHANE, a synthetic fungicide widely used in the prevention of blight on potatoes and tomatoes . . . LYKOPON — the textile industry's foremost reducing agent . . . OROPON — the first synthetic leather bating used throughout the tanning industry and the PRIMALS — resin finishes which give flexibility and water-resistance to leathers.



Bating with OROPON in Rohm & Haas experimental tannery.



Digging a field of DITHANE sprayed potatoes.



Padding and calendering equipment in the Rohm & Haas Textile Laboratory.





